



TITLE:

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CITATION:

Arakawa, Kohman Y.. STUDIES ON THE FAECAL PELLETS OF MARINE INVERTEBRATES
(EXCLUDING MOLLUSCS) I. PUBLICATIONS OF THE SETO MARINE BIOLOGICAL
LABORATORY 1971, 19(4): 231-241

ISSUE DATE:

1971-12-27

URL:

<http://hdl.handle.net/2433/175721>

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STUDIES ON THE FAECAL PELLETS OF MARINE INVERTEBRATES (EXCLUDING MOLLUSCS) I

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With 5 Text-figures

The coprolites or fossil excreta from certain ancient marine invertebrate animals have been suggested by some former workers (MOORE, 1931 & 1939; EDGE, 1934; SCHÄFER, 1953; HATAI et al., 1970 etc.) to be of geological and palaeoecological values, because they have often been found, together with other fossil remains, in many strata in different parts of the world. Since the fossil pellets are usually preserved detached from their original producers, it is hardly possible to determine the exact producers of the pellets. However, this may be conjecturally done to some extent by comparison with similar features of pellets that are produced actually by living organisms.

The data presented in this paper are based largely upon observations which have incidentally been done during the scatological survey on molluscs in these few years. This paper, therefore, includes descriptions of the shape, size and gross diagnostic characteristic of faecal pellets from twenty-one species of living marine invertebrates excluding molluscs.

Before passing into descriptions, I wish to express my thanks to Dr. Ryonosuke KITAMORI, Tokai Regional Fisheries Research Laboratory, for identifying polychaetes observed in this work, to Mrs. Sayoko SADA of our Station for preparing the Text-figures in this paper and to Dr. Takasi TOKIOKA for editorial advices.

Descriptions

ANNELIDA Polychaeta

Family Arenicolidae

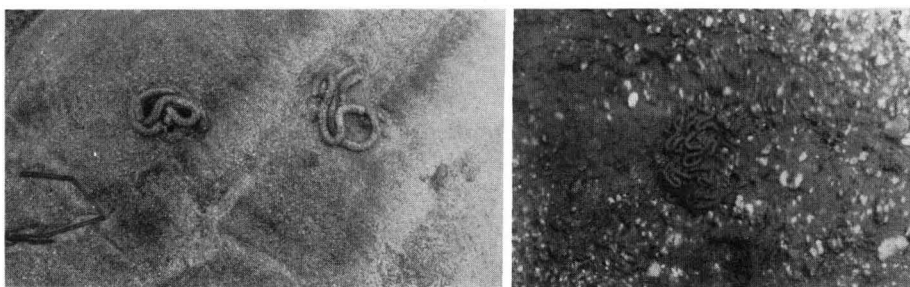
1) *Arenicola cristata* STIMPSON (Text-fig. 1. left)

Faecal rods are voided accumulated as noodle-like piles around the burrow entrance of the animal. The piles are easily disintegrated by wave action, as they

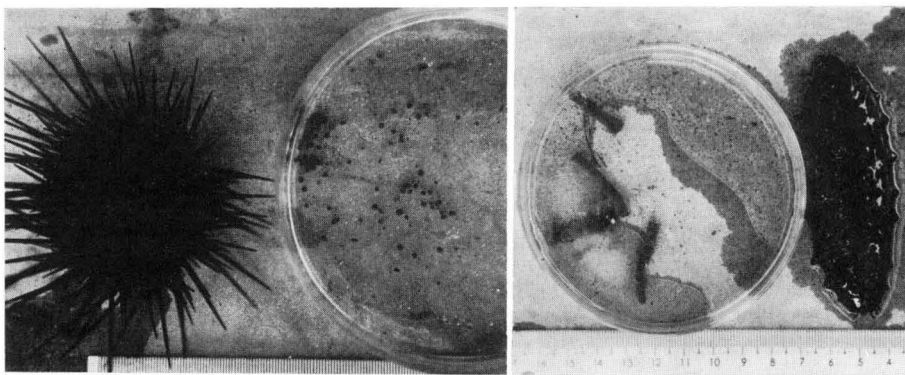
are composed of loosely bound muddy sands. The surface of the rods is unsculptured, coarse in texture and sandy in appearance. The rods are 3 mm or so in breadth and the piles are 30–40 mm in diameter, though may become much larger in situations sheltered from wave action.

Locality: Shikanoshima, Fukuoka Prefecture

Remarks: The faecal piles from *Lumbrinereis* sp. described by EDGE (1934) are similar in appearance to those of the present species. WELLS (1949) made interesting studies on defaecation behaviour in *Arenicola marina* L.



Text-fig. 1. Faecal piles of: (left) *Arenicola cristata* STIMPSON and (right) an unidentified polychaete.



Text-fig. 2. Faecal pellets and their producer. (left) *Anthocidaris crassispina* (AGASSIZ), (right) *Stichopus japonicus* SELENKA.

Family Capitellidae

2) *Notomastus* sp. (Text-fig. 3, F)

Faecal pellets are oval in shape with rounded ends and fine in surface-texture. The colour varies from greyish green to greenish black according to the kind of food taken.

Locality: Kure Bay, Hiroshima Pref.

Measurements:-

Size of animal mm	Pellet-number	Pellet-size					
		Breadth (B) mm		Length (L) mm		Ratio (L/B)	
		Range	Mean	Range	Mean	Range	Mean
1.8 × (50.0 +)	11	0.36—0.31	0.33	0.68—0.78	0.73	2.06—2.38	2.22
1.5 × (65.0 +)	15	0.33—0.43	0.39	0.70—0.90	0.77	1.80—2.24	1.99
1.5 × (45.0 +)	11	0.46—0.50	0.47	0.85—0.92	0.88	1.74—1.91	1.85
1.5 × 97.0	10	0.38—0.43	0.41	0.80—0.88	0.83	1.91—2.21	2.05
Average mean ratio							2.03

Family Cirratulidae

3) *Cirratulus* sp. (Text-fig. 3, E)

Pellets are shed in ellipsoids, usually carrying an amount of mucus. They are rather coarse in surface-texture and greyish or yellowish brown in colour. The exact shape of pellets seems somewhat variable, and in starved animals the pellets may be thinner and irregular in shape.

Locality: Kure Bay, Hiroshima Pref.

Measurements:-

Size of animal mm	Pellet-number	Pellet-size					
		Breadth (B) mm		Length (L) mm		Ratio (L/B)	
		Range	Mean	Range	Mean	Range	Mean
1.5 × (20.0 +)	3	0.75—0.85	0.80	1.05—1.50	1.32	1.40—1.88	1.65
3.0 × (32.0 +)	1	0.45		1.15		2.56	
3.5 × (15.0 +)	1	0.50		1.10		2.20	
Average mean ratio							2.14

4) *Cirriformia tentaculata* (MONTAGU) (Text-fig. 3, C)

Faecal pellets are discharged in rods without any surface groovings. Sometimes, they form short rods or comma-shaped beads. The colour and surface-texture of pellets are considerably variable according to the kind of food taken. But, generally, they are greenish brown in colour and rather coarse in texture.

Locality: Kure Bay, Hiroshima Pref.

Measurements:-

Size of animal mm	Pellet-number	Breadth of faecal rod mm
3.0 × 20.0	1	0.75
5.0 × (19.0 +)	1	0.50
1.5 × 11.0	1	0.60
3.5 × 27.0	1	0.50
2.5 × 20.0	1	0.50
5.0 × (27.0 +)	1	0.55
1.9 × 15.0	1	0.48
5.7 × 41.0	1	0.50
2.0 × 12.0	1	0.60

Remarks: Faecal rods from this species are very similar in appearance to those of *C. filigera* (DELLA CHIAJE) described by KRAEUTER & HAVEN (1970).

Family Sabellidae

5) *Potamilla leptochaeta* SOUTHERN (Text-fig. 3, A)

Faecal rods of this species are constricted at irregular intervals and twisted at places. The texture is fine and the colour is greyish brown. Frequently, the pellet-surface may be chapped finely. Pellets discharged from a 55 mm long animal fluctuate from 0.50 mm to 0.80 mm in diameter.

Locality: Ondo, Hiroshima Pref.

Family Serpulidae

6) *?Protula tubularia* (MONTAGU) (Text-fig. 3, B)

Pellets are short rods or elongate ellipsoids. They are uneven and coarse in surface-texture, rather soft in consistency and grey in colour. Pellets produced by a 16 mm long animal are 0.85 mm in breadth on an average.

Locality: Ondo, Hiroshima Pref.

Remarks: EDGE (1934) figured a similarly shaped pellet from a 'Serpulid-sp.'. The pellets of *Eupomatus dianthus* reported by KRAEUTER & HAVEN (1970) are much more elongated than those of the present species.

ECHIUROIDEA Echiurida

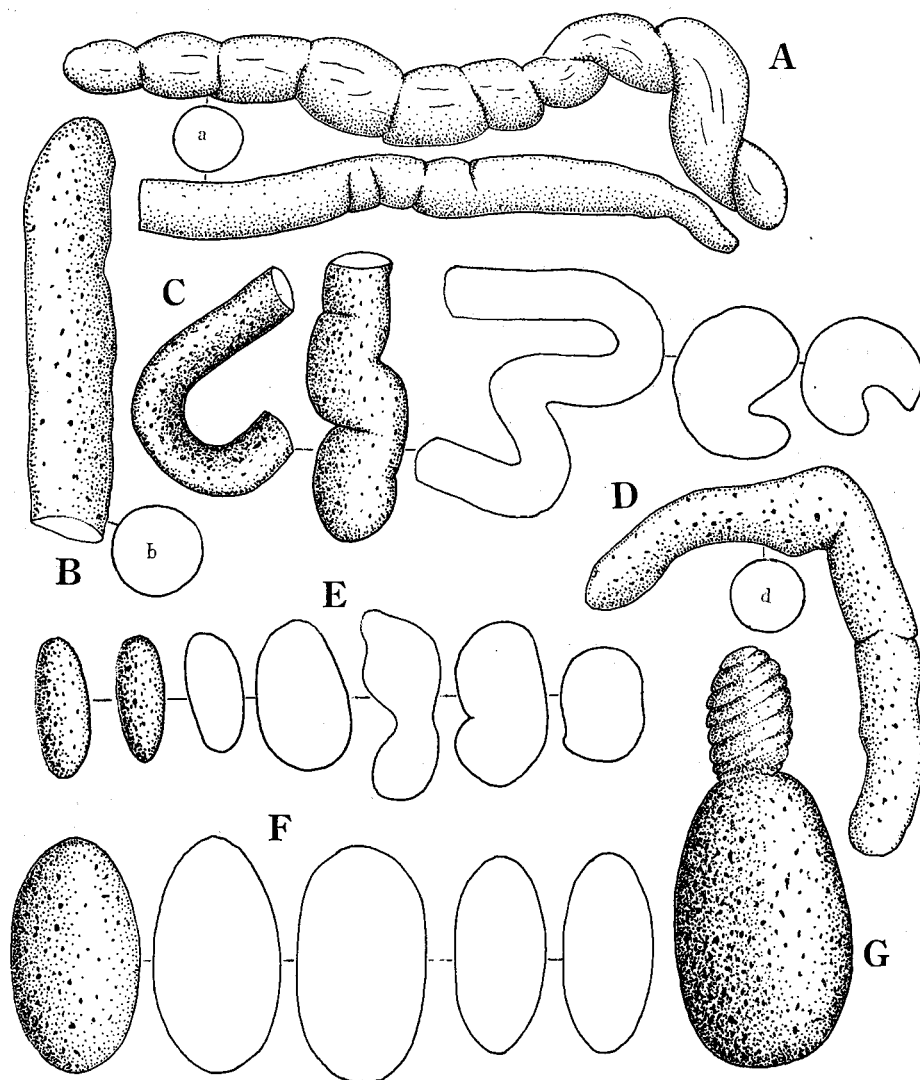
Family Thalassematidae

7) *Ikedosoma gogoshimense* (IKEDA) (Text-fig. 3, G)

Pellets are shed scattered around the burrow entrance of the animal. They are bottle-shaped and consist of two distinct portions. The trunk is large, oval in

outline, and with a coarse sandy appearance but no surface groovings; it is composed of a large amount of detritus mixed with undigested skeletal matters and some sand grains. The nose is small, ellipsoidal in shape, fine in consistency and with fine spiral grooves. Pellets shed from a 75 mm long animal average $9.0 \text{ mm} \times 3.5 \text{ mm}$ in size.

Locality: Mukaishima, Hiroshima Pref.



Text-fig. 3. Faecal pellets of: A. *Potamilla leptochaeta* SOUTHERN (a. cross section), B. *?Protula tubularia* (MONTAGU) (b. cross section), C. *Cirriformia tentaculata* (MONTAGU), D. *Siphonoma* (*Dasmosiphon*) *cumanense* (KEFERSTEIN) (d. cross section), E. *Cirratulus* sp., F. *Notomastus* sp., G. *Ikedosoma gogoshimense* (IKEDA).

SIPUNCULOIDEA Sipunculoidea

Family Sipunculidae

8) *Siphonosoma (Damosiphon) cumanense* (KEFERSTEIN) (Text-fig. 3, D)

Faecal pellets are plain rods unevenly and coarsely surfaced. They are formed almost of detrital materials mixed these with partially digested fragmentary pieces and some sand grains. The colour varies from sandy grey to blackish grey according to the kind of food taken. The pellet-diameter fluctuates from 0.9 to 1.5 mm, for an 100 mm long animal.

Locality: Ondo, Hiroshima Pref.

ARTHROPODA Crustacea

Family Balanidae

9) *Balanus amaryllis* DARWIN (Text-fig. 4, H)

Pellets are short rods, chocolate brown in colour and very fine in surface consistency. The ends of pellets are broken but, at times, rounded. For an animal with a shell 25 mm × 25 mm, the breadth of pellets ranges from 1.0 to 1.1 mm.

Locality: Akitsu, Hiroshima Pref.

Remarks: EDGE (1934) figured a similarly shaped pellet for *B. tintinabulum*. The pellets of *B. eburneus* GOULD and *B. improvisus* DARWIN described by KRAEUTER & HAVEN (1970) are exactly similar in appearance to those of the present species.

ECHINODERMATA Echinoidea

Family Temnopleuridae

10) *Temnopleurus toreumaticus* (LESKE) (Text-fig. 4, I)

Faecal pellets of this species are quite variable in shape; roughly spherical, triangular, ovoid or ellipsoidal. They are coarse in texture, sandy in appearance, and composed of large amount of undigested skeletal materials mixed these with detrital matters and some sand grains.

Locality: Ondo, Hiroshima Pref.

Measurements:-

Size of animal mm	Pellet-number	Pellet-size					
		Breadth (B) mm		Length (L) mm		Ratio (L/B)	
		Range	Mean	Range	Mean	Range	Mean
No measurements	7	1.20—1.60	1.46	1.40—5.50	2.91	1.08—3.44	2.00

Remarks: EDGE (1934) reported that *Lytechinus aminensis* sheds pellets of variable size and shape too.

Family Echinometridae

11) *Anthocardis crassispina* (A. AGASSIZ) (Text-fig. 4, K and Text-fig. 2, left)

Pellets are roughly spherical in shape, yellowish brown in colour, fine in texture and soft in consistency. The pellet-diameter fluctuates from 1.0 mm to 2.0 mm for an animal with a shell ca. 55 mm broad.

Locality: Ondo, Hiroshima Pref.

Family Loveniidae

12) *Echinocardium cordatum* (PENNANT) (Text-fig. 4, L)

Faecal pellets of this species are usually spherical in shape and soft in consistency. The cross section of pellets shows that the materials are packed in concentric layers according to the particle size and the nature of food; in the pellets examined coarser and dark materials are concentrated at the centre, while finer and yellowish grey materials are deposited in the peripheral layers.

Locality: Ondo, Hiroshima Pref.

Measurements:-

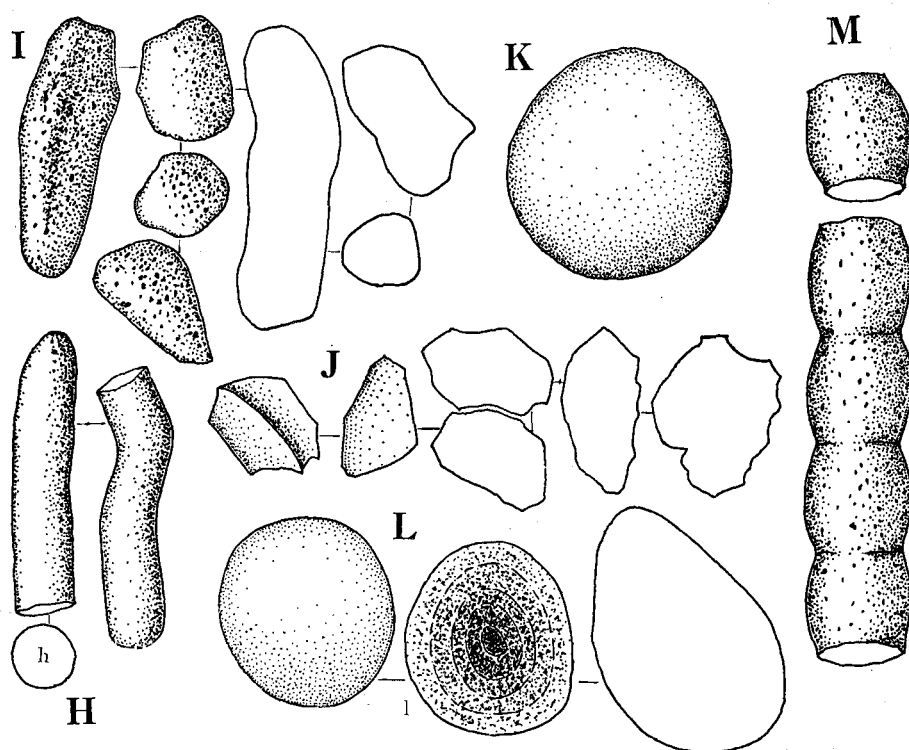
Size of animal mm	Pellet-number	Pellet-size					
		Breadth (B) mm		Length (L) mm		Ratio (L/B)	
		Range	Mean	Range	Mean	Range	Mean
38 × 34	1	—	5.00	—	6.20	—	1.24
30 × 27	3	2.10—2.60	2.37	2.80—3.20	3.00	1.17—1.43	1.27
38 × 30	2	4.30—4.80	4.55	5.40—5.90	5.65	1.23—1.26	1.25
33 × 30	2	2.10—2.90	2.50	2.50—3.10	2.80	1.07—1.19	1.12
33 × 32	2	2.80—3.10	2.95	3.70—4.60	4.15	1.19—1.64	1.41
36 × 33	3	1.20—2.20	1.80	2.40—3.20	2.93	1.45—2.00	1.63
44 × 42	2	3.40—3.70	3.55	4.50—5.00	4.75	1.32—1.35	1.34
Average mean ratio							1.32

Holothuroidea

Family Stichopodidae

13) *Stichopus japonicus* SELENKA (Text-fig. 4, M and Text-fig. 2, right)

Faecal pellets are rod-shaped and constricted at regular intervals. They are very coarse in texture, soft in consistency and dark grey in colour. The rods fluctuate



Text-fig. 4. Faecal pellets of: H. *Balanus amaryllis* DARWIN (h. cross section), I. *Tennopleurus toreumaticus* (LESKE), J. *Hemicentrotus pulcherrimus* (A. AGASSIZ), K. *Anthocardia crassispina* (A. AGASSIZ), L. *Echinocardium cordatum* (PENNANT) (l. cross section), M. *Stichopus japonicus* SELENKA.

from 6.0 mm to 7.5 mm in breadth and constrictions are spaced by 7.0 mm for a 220 mm long animal.

Locality: Mukaishima, Hiroshima Pref.

Measurements:-

Size of animal mm	Breadth of faecal rod mm
75	4.0
220	6.0—7.5
52	1.5

Remarks: Pellets of *Stichopus californicus* reported by EDGE (1934) are plain rods and without any constrictions, but those of *Holothuria nigra* described by Moore (1939) are similarly constricted at intervals as in the present species.

Family Strongylocentritidae

14) *Hemicentrotus pulcherrimus* (A. AGASSIZ) (Text-fig. 4, J)

Pellets of this species are very variable in shape and show no definite characters. The colour varies from brown to green or light green according to the kind of food eaten. They are composed of a large amount of undigested algal fragments.

Locality: Ondo, Hiroshima Pref.

Measurements:-

Size of animal	Pellet-number	Pellet-size					
		Breadth (B) mm		Length (L) mm		Ratio (L/B)	
		Range	Mean	Range	Mean	Range	Mean
45×25	6	1.30—2.00	1.53	2.20—3.00	2.42	1.15—2.14	1.58

PROCHORDATA Urochorda

Family Cionidae

15) *Ciona intestinalis* (LINNÉ) (Text-fig. 5, R)

Pellets are ungrooved ribbons which are unguulate section; the texture is very coarse and made up of rather large food particles. They are brownish yellow in colour and translucent; 7.0 mm wide on an average for a 60 mm long animal.

Locality: Jigozen, Hiroshima Pref.

16) ?*C. sp.* (Text-fig. 5, S)

Faecal ribbons are crescent in section, greenish brown in colour, very soft and loose in consistency. They are usually shed in very short pieces. Both lateral fringes are thickened, while the axial region is very thin. In other respects, the ribbons are similar to those of the preceding species. Ribbons from a 25 mm long animal are 5.0 mm or so in width.

Locality: Ninoshima, Hiroshima Pref.

Family Ascidiidae

17) *Ascidia ahodori* OKA (Text-fig. 5, N)

Faecal pellets are ribbon-shaped with lateral edges inrolled so strongly as to come in contact with each other. They are greenish brown in colour and, occasionally, marked with some transverse clefts. Generally, they are formed almost entirely from fine detritus. The ribbons are 2.3 mm or so in width for a 31 mm long animal.

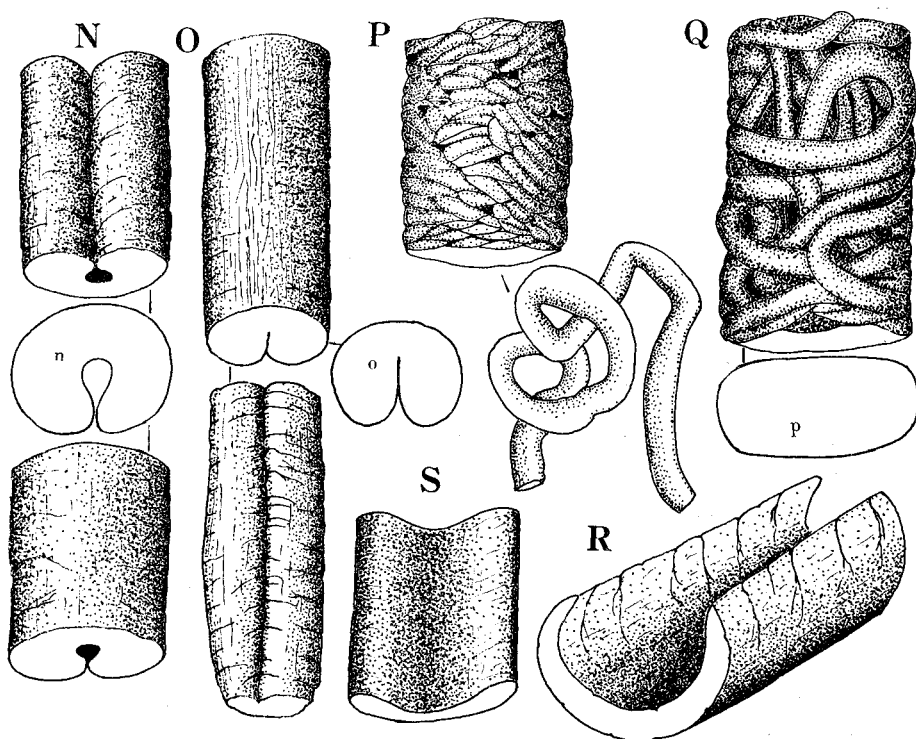
Locality: Ninoshima, Hiroshima Pref.

Family Styelidae

18) *Styela partita* (STIMPSON) (Text-fig. 5, P)

Faecal rods of this species are built up compactly of noodle-like constituent rodlets. They are usually discharged in shorter pieces and are elongate oval in cross section and yellowish brown in colour. The rods voided from a 40 mm long animal are about 3.4 mm in breadth and constituent rodlets are 0.35 mm in breadth.

Locality: Ondo, Hiroshima Pref.



Text-fig. 5. Faecal pellets of: N. *Ascidia ahodori* OKA (n. cross section), O. *Styela clava* HERDMAN (o. cross section), P. *S. partita* (STIMPSON), Q. *S. plicata* (LESUEUR) (p. cross section), R. *Ciona intestinalis* (LINNÉ), S. ?C. sp.

19) *S. plicata* (LESUEUR) (Text-fig. 5, Q)

The pellets of this and the preceding species are so much alike in their general structure that it is impossible to distinguish them from each other. The pellets shed by a 60 mm long animal average 6.0 mm in width of rod and 0.7 mm in breadth of constituent rodlet.

Locality: Ninoshima, Hiroshima Pref.

20) *S. clava* HERDMAN (Text-fig. 5, O)

Pellets of this species are of the type similar to those of the preceding two, though

they are grooved longitudinally by a single channel and the constituent rodlets are rather blurred. The rods are yellowish brown in colour and fluctuate from 2.3 mm to 3.0 mm in width for an 110 mm long animal.

Locality: Jigozen, Hiroshima Pref.

Remarks: EDGE (1934) described rod-like pellets from *Styela montereyensis*, which are unsculptured and thus differ somewhat from any of *Styela* species referred to above.

Family Pyuridae

21) *Halocynthia roretzi* (VON DRASCHE)

Faecal pellets are shed in long continuous rods. They are uneven, very coarse in texture and greyish green in colour. The pellet-breadth averages 1.12 mm for an examined animal (ca. 100 mm).

Locality: Mukaishima, Hiroshima Pref.

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